(12) UK Patent Application (19) GB (11) 2 385 197 (13) A

(43) Date of A Publication 13.08.2003

(21) Application No 0202894.2

(22) Date of Filing 07.02.2002

(71) Applicant(s)
DenseLight Semiconductors Pte Ltd
(Incorporated in Singapore)
6 Changi North Street 2,
Changi North Industrial Estate,
Singapore 498831, Singapore

(72) Inventor(s)
Kian Hin Victor Teo
Yee Loy Lam
Yuen Chuen Chan
Cher Liang Randall Cha
Kin Chung Kong
Siew Ling Chan
Geok Ing Ng

(51) INT CL[7]
H01S 5/026

(52) UK CL (Edition V)
H1K KED K1EA K1EA1 K1EB K1ED K9B1 K9B1A

(56) Documents Cited
EP 0827211 A2
US 6115521 A
US 6137121 A
US 5771322 A

(58) Field of Search
UK CL (Edition T) H1K KED KQAMX KQAX
INT CL[7] G02B, H01L, H01S 5/026
Other: Online: WPI, PAJ, EPODOC

(74) Agent and/or Address for Service
Gill Jennings & Every
Broadgate House, 7 Eldon Street,
LONDON, EC2M 7LH, United Kingdom

(54) Abstract Title

Semiconductor laser with monitor photodetector arrangement

(57) There is provided a semiconductor device for aligning a laser (1) with a passive monitor photodetector (2) for quantitative measurements. The semiconductor device comprises: a semiconductor laser (1); a photodetector (2); and a light turning structure (3) bonded on a first substrate. The light turning structure (3) is arranged to deflect light from the back facet of the laser (1) onto the photodetector (2). The light turning structure (3) comprises an etched cavity (4) formed in a separate substrate (6) bonded to the first substrate. Light from the laser may be guided along a groove (7). A reflecting mirror may be provided in the path of the light exiting the laser (1). Where the separate substrate (6) is transparent to the characeristic wavelength of the laser (1), the photodetector (2) may be formed on the underside of the separate substrate (6).

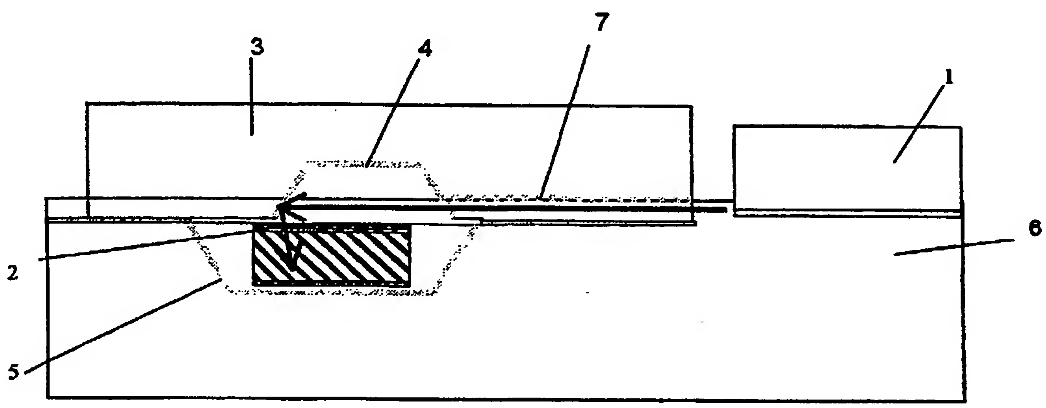

Fig. 1A

GB 2 385 197 A

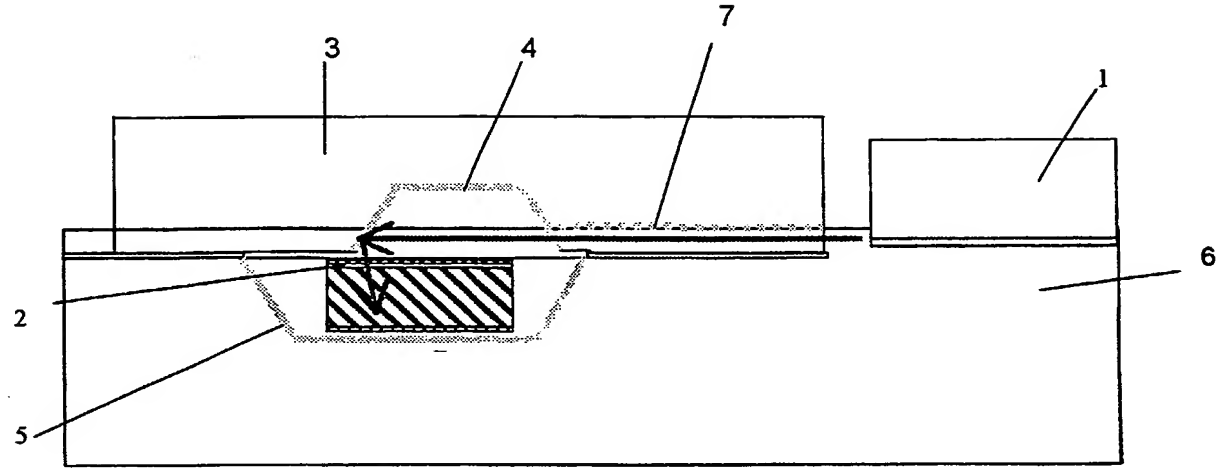

Fig. 1A

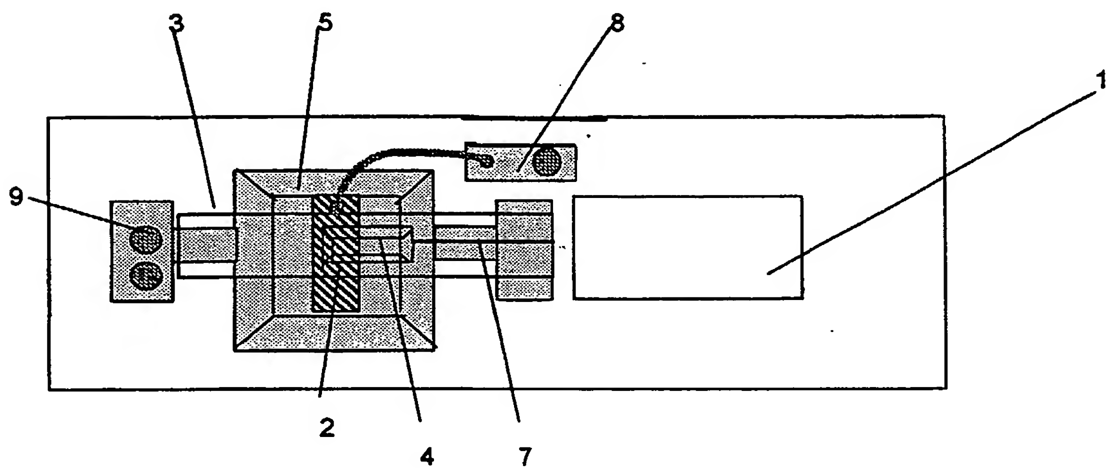

Fig. 1B

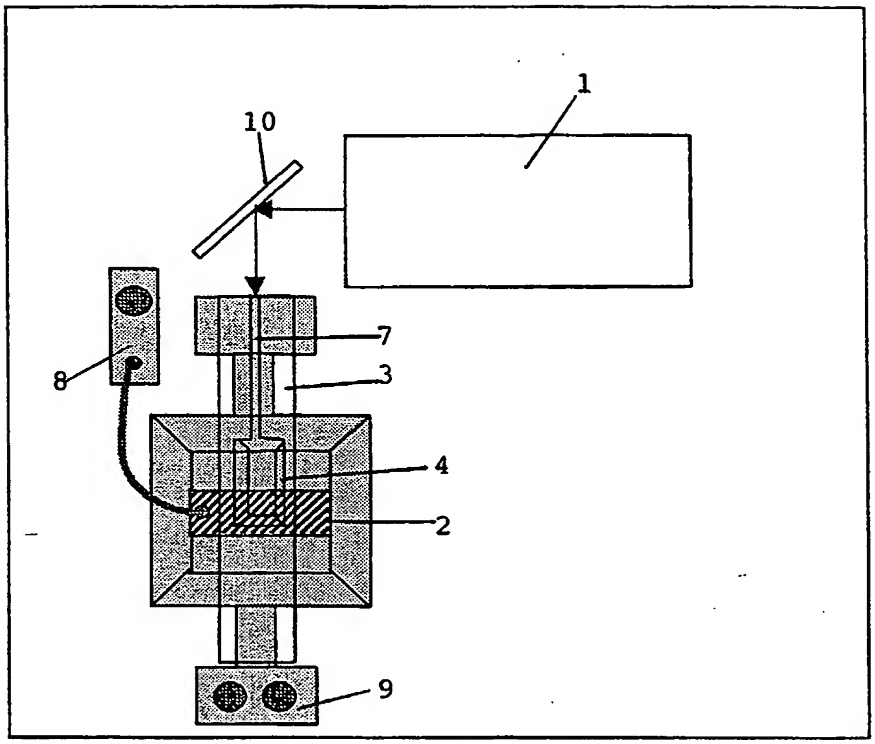

Fig. 2

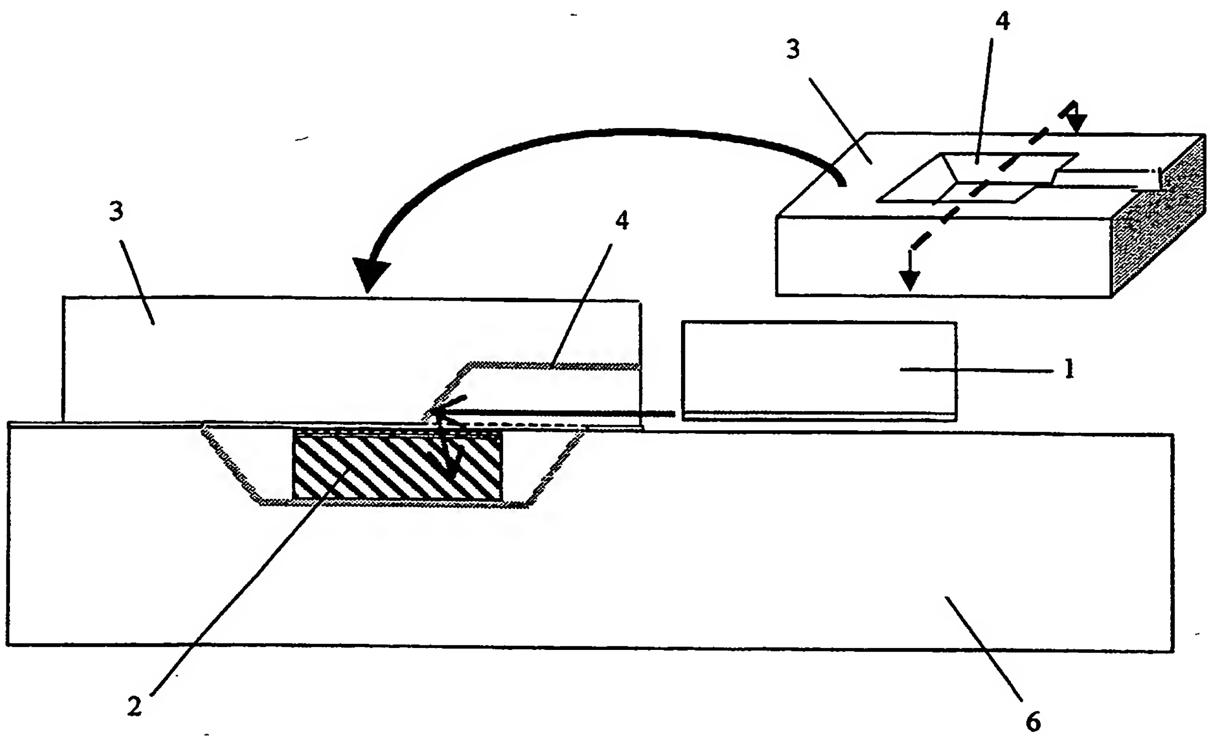

Figure 3

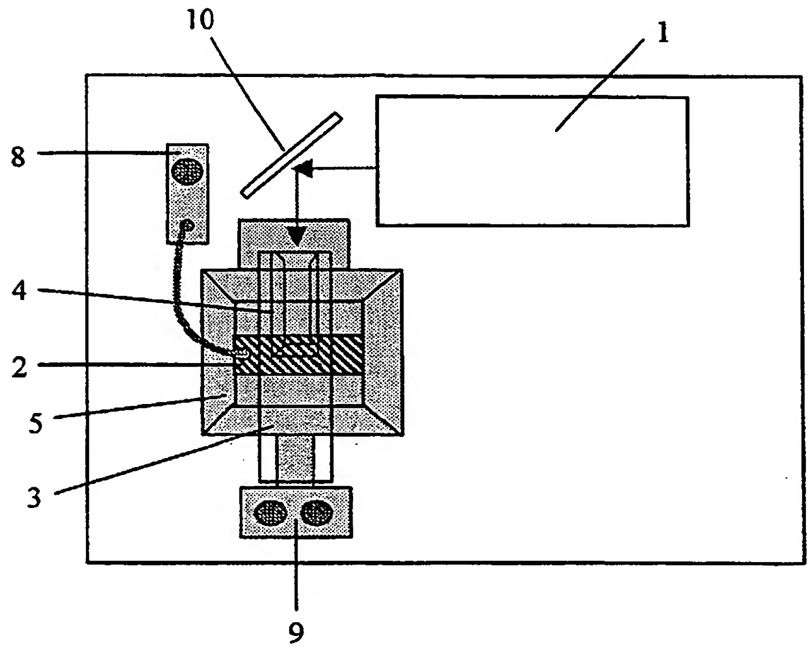

Figure 4

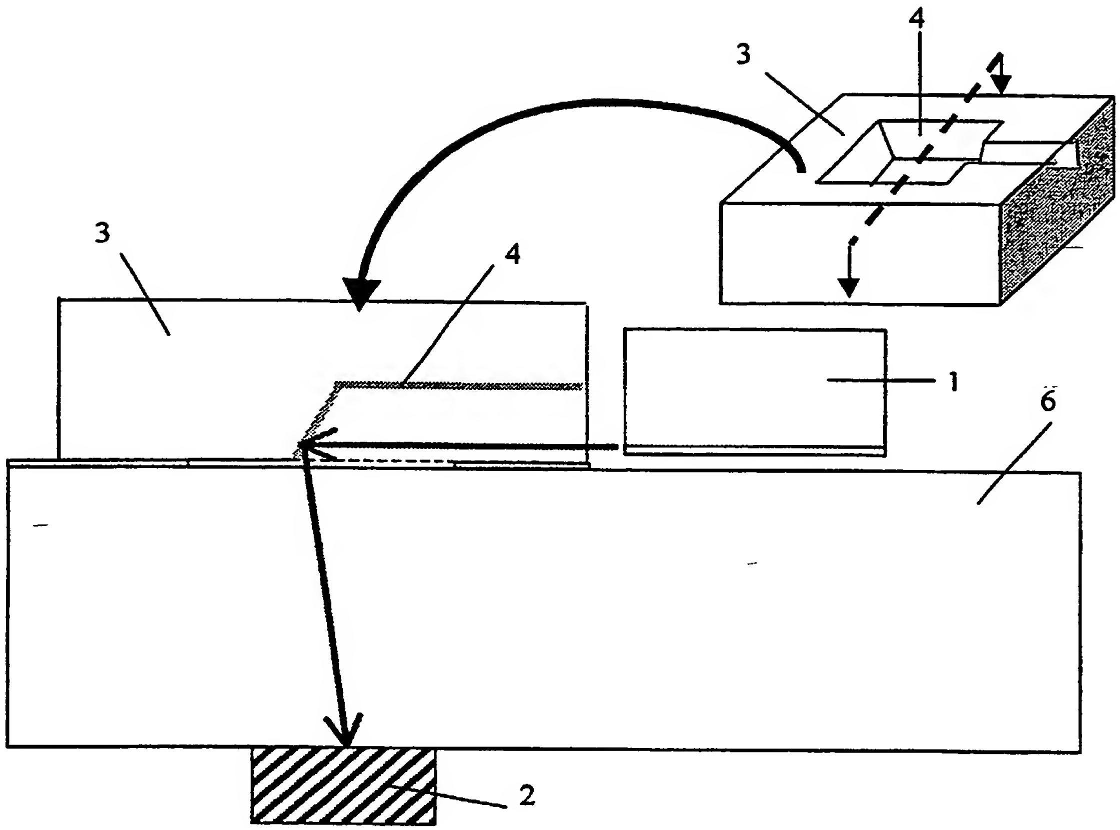

Figure 5

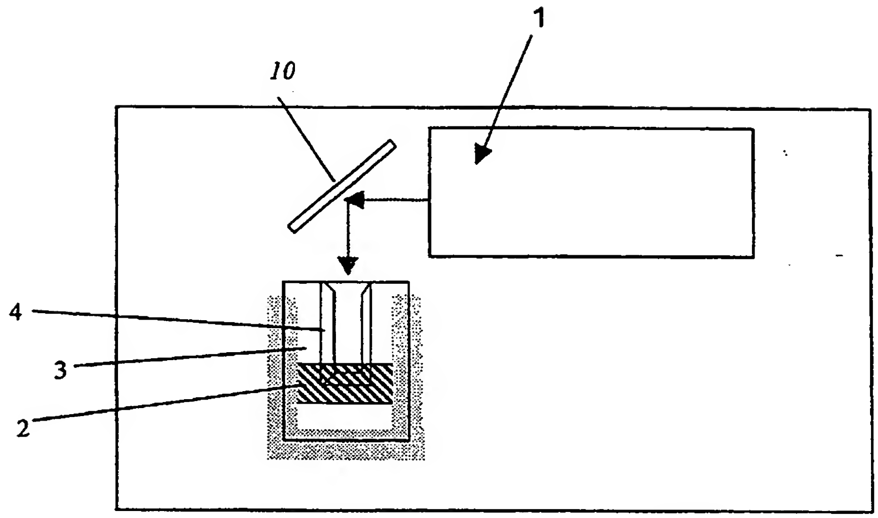

Fig. 6

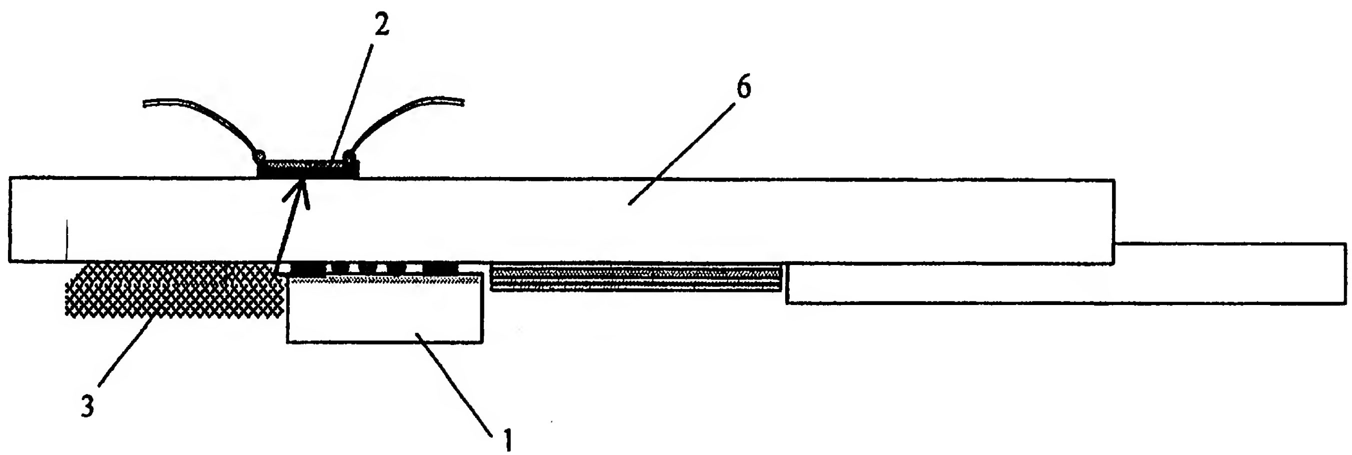

Figure 7

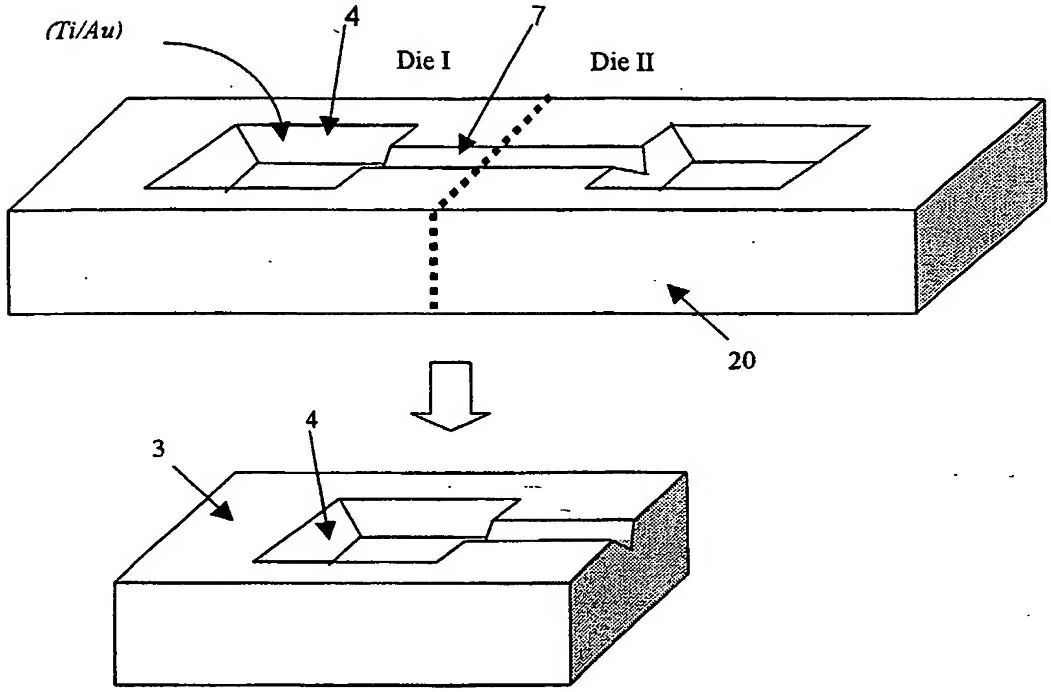

Fig 8

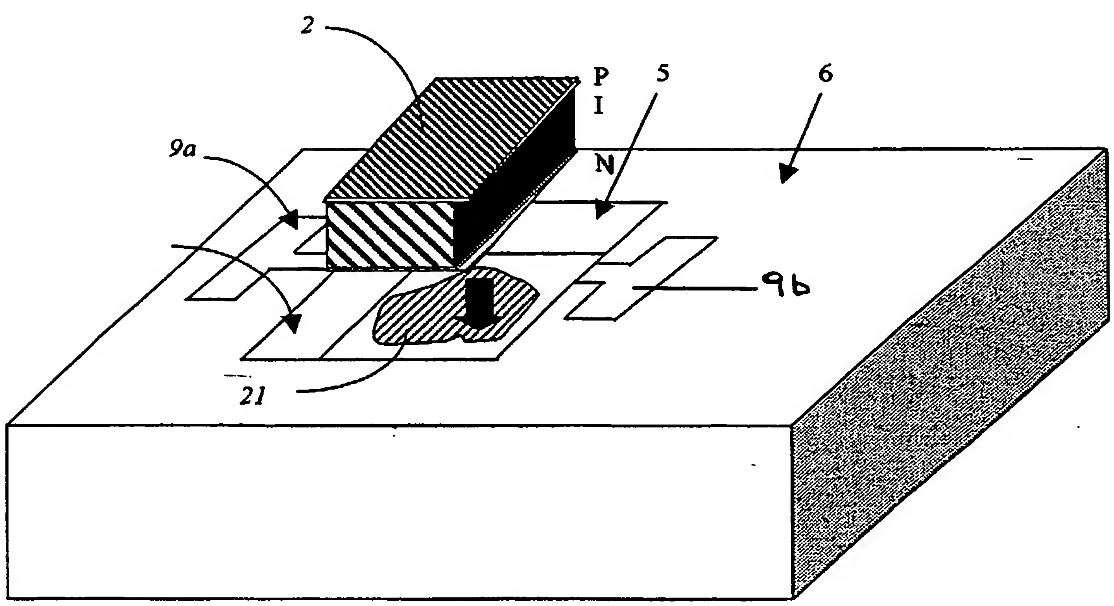

Fig. 9

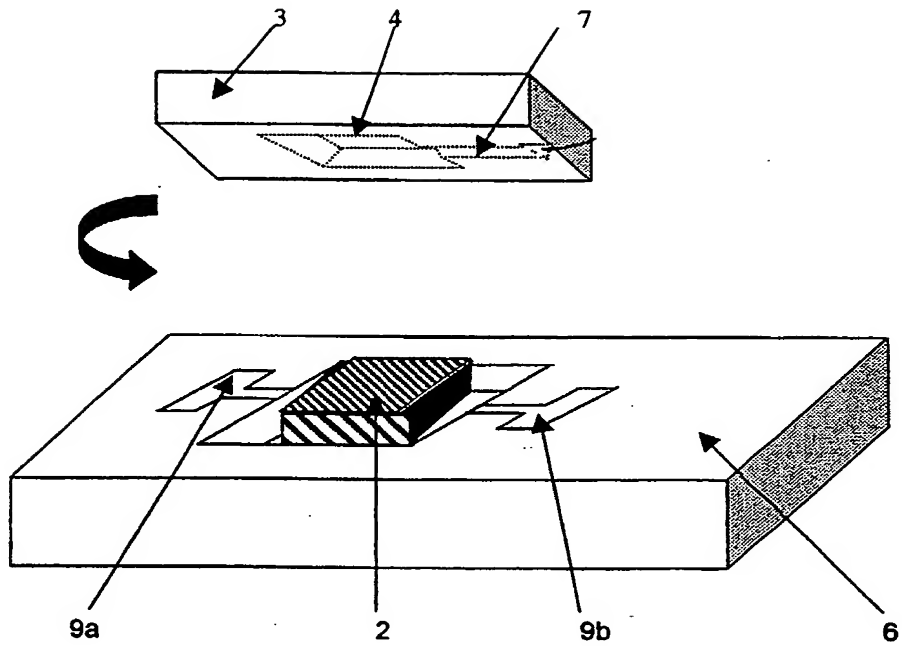

Fig. 10

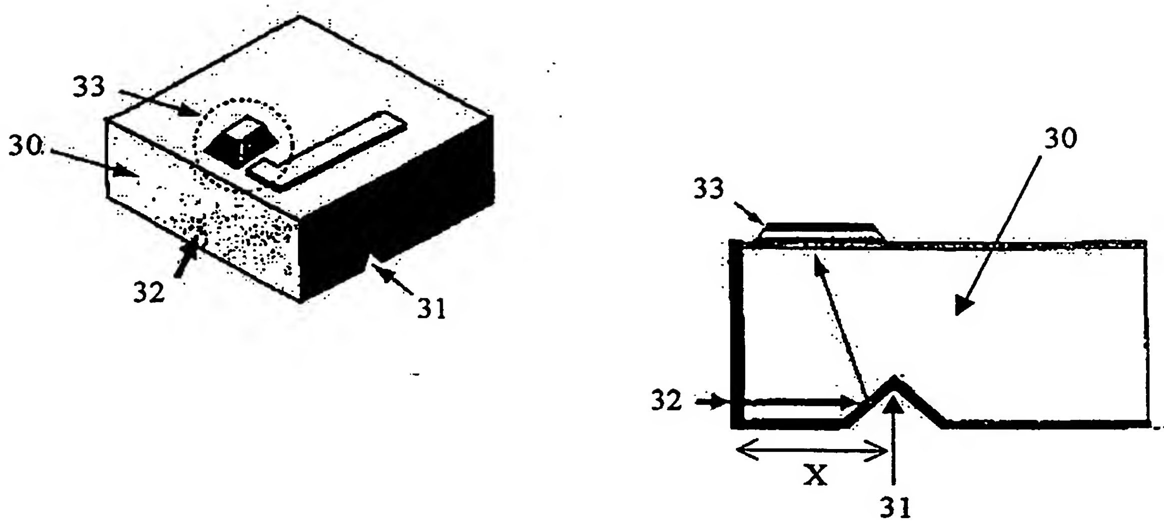

Figure 11 (Prior Art)

2385197

ARRANGEMENT TO GUIDE LASER LIGHT INTO PASSIVE PHOTODETECTOR FOR QUANTITATIVE MEASUREMENTS

Field of the Invention

Most semiconductor lasers of today have concomitant photodetectors built alongside them or integrated into them to measure their transmitted (or loss power). The photodetector converts the incident laser light energy into electrical energy, and the electrical response is an accurate measure of the output performance of a laser. The detector is commonly located at the posterior end of the laser emitting light (or power) of certain wavelength range.

Background to the Invention

Most photodetectors are fabricated simultaneously alongside the actual laser device fabrication, i.e., active device integration. However, some are constructed independently, and are later mounted onto the same platform, e.g., a coupling bench, onto which the laser will also be mounted. These photodetectors are passive detectors, and they function in the same manner as their active integrated counterparts. The fundamental construction flow is similar for both, but each has different design and construction limitations.

	Active Photodetector	Passive Photodetector
Process complexity (number of steps)	Less	More
Design complexity (metal routing, voltage biasing)	More	Less
Size	Smaller	Larger
Versatility (e.g. material selection, detector location, detector design to suit application, accommodation level, etc)	Low	Very High

Passive photodetectors are definitely more preferable under circumstances in which a high level of device integration with minimum design complexity is required. The separate construction of the laser and photodetector as two different entities simplifies the whole manufacturing process of both devices because process considerations regarding device integration is confined to only that individual device

being fabricated. In the case of active device integration, there are serious concerns over which process steps making the laser could damage the parts of an existing photodetector or vice versa.

However, it is often the case that there are worse misalignment problems in passive device integration than in active device integration. The reason is simply because two individual pieces are mounted onto one common platform, or one piece is adjoined to the other which has a larger area. Such circumstances readily introduce many tolerance considerations and other dependencies. For example, if dispensed solders are being used to mount both laser and photodetector on a coupling bench, it is necessary to control the thickness of the laser and photodetector, the surface flatness of the optical bench, the warping of the optical bench, the amount of dispensed solder, and the orientations of the photodetector and lasers when they are placed on the bench, and etc. Each of these few aforementioned factors can incur high levels of misalignment, not to mention further on their combination effects. Consequently, to preserve or value the worth/quality of both the laser and the photodetector, the solicitation of a good methodology to achieve good alignment between these two devices is urgent and totally essential.

A further problem to overcome is to avoid the 'same' light, the intensity of which is being measured, being reflected back into the laser. It is desirable to fully 'capture' the diverging light coming out from the laser backend.

Figure 11 shows a prior art design [Kato et al, IEEE Photon.Technol.Lett. Volume 11, pp 709 (1999)] in which light 32 from the back facet of a laser enters an InP substrate 30 and is reflected from a V-groove 31 which is etched along a (111) plane of the substrate 30. The light is reflected from a surface of the V-groove and up through the substrate into a photodetector 33. In this arrangement, there is significant divergence of the light between entering the substrate 30 and reflecting from the V-groove 31. This cannot be reduced by moving the reflecting surface closer to the laser, as the distance X is limited by the size of the photodetector 33 and the angle of the V-groove. There is further divergence of the beam between the reflecting surface and the photodetector. Divergence of the beam means that less light is collected by the photodetector and also, multiple reflections in the substrate cause stray light to be reflected back into the laser.

Summary of the Invention

According to the present invention, a semiconductor device comprises a semiconductor laser, a photodetector and a light turning structure bonded on a substrate, wherein the light turning structure is arranged to deflect light from the

back facet of the laser, wherein the light turning structure comprises an etched cavity formed in a separate substrate bonded to the first substrate.

Preferably, the light turning structure comprises a silicon piece with an etched and metallized cavity.

In one embodiment, the photodetector resides in a trench in the first substrate and a light turning structure is located over the trench and reflects light down into the photodetector. In this embodiment, the light turning structure preferably comprises a trapezoidal cavity having a V-groove entering the cavity, and the light turning structure is arranged such that light from the laser enters the cavity through the V-groove. The length of the V-groove can be increased to minimise the amount of light reflected back into the laser.

In a second embodiment, the photodetector is bonded to the opposite side of the substrate to the laser, and the light turning structure is arranged at the back facets of the laser to deflect light down through the substrate into the photodetector. In this embodiment, the reflector can be placed very close to the back facet of the laser, reducing the problem of divergence, as the reflector "catches" more of the light. Also the photodetector can be made much larger as it is located on the opposite side of the substrate. The detector area can therefore be made much larger again, with the object of catching more light. The geometry of this arrangement is such that light reflected from the detector/substrate interface cannot be reflected back into the laser.

In both embodiments, a reflecting mirror may be placed between the laser and the light turning structure to further reduce reflection back into the laser.

Brief Description of the Drawings

Figure 1A shows a side view of a first embodiment;

Figure 1B shows a plan view of the first embodiment;

Figure 2 shows a plan view of a second embodiment;

Figure 3 shows a side view of a third embodiment;

Figure 4 shows a plan view of a fourth embodiment;

Figure 5 shows a side view of a fifth embodiment

Figure 6 shows a plan view of a sixth embodiment;

Figure 7 shows a side view of the fifth embodiment;

Figure 8 illustrates the process of manufacturing the flip light guider;

Figure 9 illustrates the bonding of the photodetector chip to the coupling bench;

Figure 10 shows the attachment of the coupling bench to the flip light guider; and,

Figure 11 shows a prior art side coupled photodiode.

Detailed Description

Figures 1A and 1B show an effective arrangement to align a laser 1 to a passive photodetector 2. An additional flip-light guider 3 is located adjacent the back facet of the laser 1. The flip light guider 3, is a silicon piece with an anisotropically etched cavity 4 (specific angled-sloped trenches, and groove channels) which is metallized, so that it is capable of 'guiding' reflected light from the back facet of the laser 1 to the passive photodetector 2. In this embodiment, the external passive photodetector 2 is a simple normal-incidence photodetector 2 that resides in a trench 5, which is created by wet etching on the coupling bench 6. The flip-light guider 3 is flipped or overturned, and covers the 'recessed' photodetector 2. Light from the laser back gets guided through the groove 7 and upon confrontation with the sloped sidewall of the cavity 4, gets reflected and beamed directly into the recessed photodetector 2. The photodetector 2 is electrically connected to the P-metal contact 8 and the N-metal contact 9; hence the concerned electrical response is measured across these two contacts.

One solution to the problem of diverging light from the laser 1 is to have the width and height of the groove 7 large enough to collect all of the divergent light beam.

There will be more light reflection for cavities with smaller groove width, than for the reverse case of larger groove width; similarly, a shallower groove 7 will give rise to more reflection as compared to a deeper groove.

If we are still very concerned over the reflection issue, we can choose to construct our device as illustrated in Figure 2. In this embodiment, we introduce a reflecting mirror 10 placed at the back of the laser 1 but at a calculated angle; the flip-light guider 3 and the recessed photodetector 2 are now positioned at an orientation to receive the laser light reflected from the mirror 10. This configuration further minimizes the reflection of light back into the powered laser 1. However, we could suffer a decrement in the intensity of the actual reflected light, and inaccuracy of our measurement since the light beam needs to travel a longer path distance.

Figure 3 shows an embodiment in which the cavity 4 is a halved trench to reflect the beam to a recessed photodetector 2. This is a more compact design than that of Figures 1 and 2. Figure 4 is a modification of the embodiment of Figure 3 except that a reflecting mirror 10 is introduced. Figure 5 illustrates that we can use

the halved trench but the photodetector 2 is now direct wafer bonded to the backside of the coupling bench 6. This is applicable for a silicon optical bench 6 since silicon is transparent to wavelengths at near infra-red range. Figure 6 is again a modification of the embodiment of Figure 5, with the introduction of a reflecting mirror 10.

Figure 7 illustrates more clearly how the geometry of the embodiment of Figure 5 prevents back reflection into the laser 1. The geometry is such that the photodetector 2 can be located almost directly on the opposite side of the optical bench 6 to the laser 1 such that reflections from the photodetector/bench interface cannot re-enter the back facet of the laser 1.

Furthermore, the photodetector 2 can be made large enough to collect all the light reflected from the flip-light guider 3.

Figures 8 to 10 illustrate the method of construction of the device according to the present invention. Anisotropic wet etching is performed on a silicon substrate 20, followed by metal evaporation onto the whole wafer and dicing to form individual guiders 3.

After wet-etching a trench 5 in the coupling bench 6, metal (Au/TiW or Au/Pt/Ti) is evaporated across the wafer, electroplated (Au/Sn) and patterned to form two contact pods 9a, 9b. Solder paste 21 is dispersed into the etched trench 5 before placing the prefabricated slab photodetector 2 into the trench 5.

As shown in Figure 10, the flip-light guider 3 is overturned and placed on the plated Au/Sn pads 9a,9b of the coupling bench 6. The cavity depression on the flip-light guider 3 is designed to accommodate the height of the photodetector on the coupling bench 6. The flip-light guider 3, which has its surface totally covered with Au, can only be bonded to the 2 Au/Sn plated pads 9a,9b upon heat treatment. The V-groove portion 7 of the flip-light guider 3 is directed to back end of the laser 1, which will be placed on same coupling bench 6 as the photodetector 2 and flip-light guider 3, and acts as light channel leading light from backend facet of the laser 1 to the sloped face of the trench 4 and redirecting light to the photodetector 2.

CLAIMS:

1. A semiconductor device comprising a semiconductor laser, a photodetector and a light turning structure bonded on a first substrate, wherein the light turning structure is arranged to deflect light from the back facet of the laser, wherein the light turning structure comprises an etched cavity formed in a separate substrate bonded to the first substrate.

2. A semiconductor device according to claim 1, wherein the light turning structure comprises an etched cavity formed in a silicon substrate.

3. A semiconductor device according to claim 1 or 2, wherein the cavity is metallized.

4. A semiconductor device according to anyone of claims 1 to 3, wherein the photodetector resides in a trench in the first substrate and the light turning structure is locatēd over the trench and reflects light into the photodetector.

5. A semiconductor device according to claim 4, wherein the light turning structure comprises a trapezoidal cavity having a groove entering the cavity, and wherein the light turning structure is arranged such that light from the laser enters the cavity through the groove.

6. A semiconductor device according to anyone of claims 1 to 3, wherein the photodetector is bonded to the opposite side of the first substrate to the laser, and wherein the light turning structure is arranged at the back facet of the laser to deflect light through the first substrate into the photodetector.

7. A semiconductor device according to any one of the preceding claims, including a reflecting mirror between the laser and the light turning structure.

8. A semiconductor device according to anyone of the preceding claims wherein the photodetector is a surface incident PIN photodetector.

The Patent Office

INVESTOR IN PEOPLE

Application No:	GB 0202894.2	**Examiner:**	Steven Morgan
Claims searched:	1-8	**Date of search:**	9 September 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H1K(KED,KQAMX,KQAX)

Int Cl (Ed.7): G02B; H01L; H01S 5/026

Other: Online: WPI, PAJ, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0 827 211 A2	(HEWLETT-PACKARD) See whole document.	1-3, 7 & 8
A	US 6 137 121	(MITSUBISHI)	
A	US 6 115 521	(TRW)	
A	US 5 771 322	(NEC)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.